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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Embedded Software and Pervasive Computing PE 0602302E, R-1 #13

Congressional program reductions	0.000	-0.141
Congressional increases	0.000	0.000
Reprogrammings	-1.729	0.073
SBIR/STTR transfer	-2.000	0.000

(U) **Change Summary Explanation:**

FY 2003	Decrease reflects SBIR transfer and minor repricing.
FY 2004	Decrease reflects congressional undistributed reductions and a below threshold reprogramming.

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COST (In Millions)	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Networked Embedded Systems Design AE-01	19.211	5.814	0.000	0.000	0.000	0.000	0.000

(U) **Mission Description:**

(U) This project extends DoD's ability to build complex embedded software systems, which are a major source of superiority in modern weapons platforms. Embedded software monitors and controls the physical environment, and lends intelligent behavior to platforms. The design and implementation of embedded software systems require an in-depth approach to information systems. Embedded systems will manage the vast quantities of information that can be accessed by physical sensors, and provided to physical actuators, in direct contact with the real world. To enable the design of these tightly integrated physical and information systems, tools to develop software for them must be extended to accommodate a wide diversity of physical world devices and environments with increasingly ambitious performance goals. Designs must support vast increases in the numbers of processors with real-time data requirements. This work radically extends software development technology to enable the modular composition of software systems subject to tight physical constraints.

(U) **Program Accomplishments/Planned Programs:**

	FY 2003	FY 2004	FY 2005
Model Based Integration of Embedded Systems	14.811	5.814	0.000

(U) The Model-Based Integration of Embedded Systems (MoBIES) program is building tools to design and test complex computer-based systems such as avionics, weapons, and communications systems. It simplifies the design of complex embedded systems by focusing on the pre-production environment rather than after-the-fact integration. The approach is to customize the design tools used by applications engineers so that controller design and systems integration can be more fully automated and the errors thereby reduced. The technology will formalize system modeling and programming tools in a common mathematical form. This analysis will allow integrated design of hardware and software from the earliest stages in system development, leading to interoperable tools, automatic systems integration, and simplified test and evaluation. The MoBIES program allows such custom-designed toolsets to be easily tailored to specific applications, resulting in more efficient, verifiable,

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scalable, and re-usable programs for complex weapon and vehicle systems applications. Its objectives are to increase by 100 percent the size of the embedded software programs that existing tools can reliably produce, and decrease by 80 percent the design time necessary to create application-specific tools.

(U) Program Plans:

- Develop methods to integrate different models of computational processes for different applications into a programmable design tool.
- Demonstrate the ability to propagate different physical constraints among design tools.
- Develop hybrid (continuous and discrete) modeling and analysis techniques for embedded systems.
- Develop and demonstrate techniques for the mathematical modeling and formal verification of model-based software generators.
- Demonstrate end-to-end tool integration in avionics, software radio, and vehicle electronics experimental platforms.
- Develop tools for automatically checking safety and reliability properties of automatically generated software.
- Demonstrate the rapid synthesis of embedded systems using customizable frameworks and model-based code generators.
- Develop techniques for integrating different commercial off-the-shelf analysis tools into a single tool environment.
- Develop and demonstrate the use of multiple-view modeling techniques for military avionics, software radio, and combat vehicular electronics applications.

	FY 2003	FY 2004	FY 2005
Adaptive Reflexive Middleware Systems	4.400	0.000	0.000

(U) The Adaptive and Reflective Middleware Systems (ARMS) program has focused on the Total Ship Computing Environment (TSCE) for the DD(X) Future Surface Combatant Family of Ships. The TSCE will be a fully integrated open system computing and information architecture that executes all tasks and mission applications optimized at the platform level, rather than the sub-system level, thus breaking down the traditional C4ISR, Combat Systems, and Ship Control System boundaries. The TSCE is a mission-critical distributed embedded system where 1) different levels of service are possible and desirable under different conditions and costs and 2) the levels of service in one dimension must be coordinated with and/or traded off against the levels of service in other dimensions to achieve the intended overall result, even in the face of battle damage or heavy workloads. The autonomous behavior of TSCE systems requires the middleware components and frameworks to adapt robustly to

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quantifiable changes in environmental conditions. In ARMS, middleware is responsible for coordinating the exchange of information efficiently, predictably, scalably, dependably and securely between remote entities by using advanced Quality of Service (QoS) capabilities of the underlying network and end systems. This program moved to PE 0602702E, Project TT-13 beginning in FY 2004.

(U) Program Plans:

- Develop adaptive protocols, algorithms, patterns, and tools that enforce security policies to enhance and support secure global resource allocation, scheduling, and control.
- Ensure stability and dependability across multi-level feedback loops in the network-centric TSCE.
- Develop meta-programming policies and mechanisms (instead of application-specific point solutions) to customize QoS -enabled middleware services and applications.
- Develop design expertise (pattern languages) to formalize the successful techniques and constraints associated with developing, generating, and validating QoS-enabled middleware frameworks and protocol/service components.
- Develop reflective techniques for synthesizing optimized real-time and embedded middleware.
- Develop languages, algorithms, and tools to configure customizable—yet standards-compliant—TSCE middleware and applications.
- Demonstrate sufficiently mature technologies that can transition, with moderate to low risk, to the DD(X) Surface Combatant Family of Ships and other DoD combat systems.

(U) **<u>Other Program Funding Summary Cost:</u>**

- Not Applicable.

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COST (In Millions)	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Software for Autonomous Systems, AE-02	21.775	7.436	0.000	0.000	0.000	0.000	0.000

(U) **Mission Description:**

(U) This project develops revolutionary control technology to enable predictable, safe, and cooperative operation of free-ranging, autonomous systems. Increased autonomy will enable combined manned and unmanned warfare. Extensive use of robotics technologies empowers future warfighters to accomplish their missions more effectively with less risk of casualties, preserving the U.S. military's most important resource. The project builds on major advances in computing and software during the past decade, which has made the practical application of complex nonlinear, hierarchical control techniques feasible.

(U) **Program Accomplishments/Planned Programs:**

	FY 2003	FY 2004	FY 2005
Common Software for Autonomous Robotics	4.501	0.000	0.000

(U) The Common Software for Autonomous Robotics program developed software technologies for large groups of extremely small and highly resource-constrained micro-robots, enabling the coordinated action of many robots to achieve a collective goal while allowing the warfighter to task and query the ensemble of robots as a group, rather than as individuals. This component addressed four critical areas: 1) coordinated behaviors, including both explicit control strategies that decompose tasks and propagate instructions to individual elements, and implicit control strategies analogous to potential fields; 2) inter-robot communications, including networking protocols that minimize energy consumption and novel alternative communications strategies such as insect-like "pheromone" communications; 3) computational architectures that range from fully distributed processing among the micro-robots themselves to off-loaded processing by a separate "proxy" processing resource; and 4) military personnel-robot interfaces, including both explicit (symbolically grounded) and novel implicit (non-symbolic) user-interface technologies. The technology has enabled distributed "swarm" systems of robots that effectively exploit the scalability of large numbers to robustly perform important military tasks such as area surveillance and mine clearing.

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(U) Program Accomplishments:

- Demonstrated energy-saving protocols with at least 70 percent savings over conventional protocol implementations.
- Integrated developmental network protocols into selected distributed robotic platforms and investigated cooperative approaches to achieve critical situational awareness in the indoor application domain.
- Demonstrated realistic mission scenarios using representative distributed robot platforms in a simulated mission context and in field experiments.
- Developed coordination techniques to support accelerated mobility and reconnaissance for cooperating platforms and developed shared representations to support collaborative communication between humans and robotic systems.
- Developed minimal-resource behavioral algorithms and simulation tools to implement highly scalable distributed approaches to simultaneous localization and mapping, communications, and threat detection.

	FY 2003	FY 2004	FY 2005
Software Enabled Control	17.274	7.436	0.000

(U) The Software Enabled Control program is improving the capabilities of control systems for advanced unmanned and manned aircraft. These control systems enhance the autonomy and reliability of both fixed- and rotary-winged unmanned aerial vehicles, and improve the performance of manned vehicles. The challenges are to mathematically model complex changes in flight conditions and vehicle status, to design fast digital control systems to automate maneuvers, and to automatically detect and recover from faults or damage. These techniques will be implemented on a common, open computing platform using a flexible programmer's interface that facilitates reuse of real-time controllers across multiple vehicles. Advanced control system development will exploit recent successes in hybrid systems research, which combine continuous-time systems with randomly occurring discrete events. Hybrid systems can then adapt to sudden changes such as aerodynamic disturbances, threat conditions, damage or failure, or limits in the flight envelope. The software to implement these controls must manage these events and guarantee stable operation throughout the execution of the mission.

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(U) Program Plans:

- Develop Open Control Platform (OCP) computing services for advanced control of fixed-wing and rotary-wing air vehicles (e.g., flight mode switching, random event handling, stability and optimization, and reliability).
- Develop and implement a system for high-confidence authority management for vehicle control and mission-management levels.
- Develop theoretical frameworks for robust hybrid control.
- Develop software customization, failure reconfiguration, and sensor and actuator resource services for unmanned aerial platforms; integrate with OCP.
- Integrate coordinated hybrid system services into OCP middleware, facilitating multi-vehicle coordinated control.
- Develop guaranteed-safe maneuver libraries and control algorithms for coordinated flight.
- Demonstrate integrated controller with active dynamic models for on-line estimation of external influences such as wind fields and carrier deck motion.
- Implement and verify adaptive real-time control algorithms on model vehicles and in hardware-in-the-loop simulation.
- Demonstrate mission-management and dynamic replanning for multiple aircraft using an F-15 and a T-33 UCAV surrogate in coordinated flight.
- Demonstrate low-level autonomous adaptive flight control using rotary-wing UAVs in complex terrains.

(U) **<u>Other Program Funding Summary Cost:</u>**

- Not Applicable.